Computed Tomography Reconstruction Codes

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The code, CCG-LCONE (for constrained-conjugate gradient for large-angle cone beam), has been used in LLNL's nondestructive evaluation work for a number of years. Code documentation has been needed to provide users and programmers with a guide to its theory and structure. This report, originally authored by LLNL retiree Jessie A. Jackson, presents a summary of the code and its documentation.

Project Goals

This project was to document the code CCG-LCONE, an x-ray reconstruction tool.

Relevance to LLNL Mission

An expanded x-ray computed tomography (CT) reconstruction tool set will benefit several LLNL programs, including the study of explosive samples for DoD and DOE, high-energy-density physics for DNT, and surveillance of weapons components. Code documentation furthers this usefulness.

FY2006 Accomplishments and Results

We have completed the report, "CCG-LCONE, CT Reconstruction Code, User and Programmer's Guide," which documents the theory behind parts of the code and the structure of the code. It functions as both a user's guide and a programmer's guide.

CCG-LCONE is used to reconstruct objects from images acquired on cone-beam radiographic systems.

There are many CT techniques to create reconstructed objects. These methods consist of processing the projection data by filtering, scaling and/or

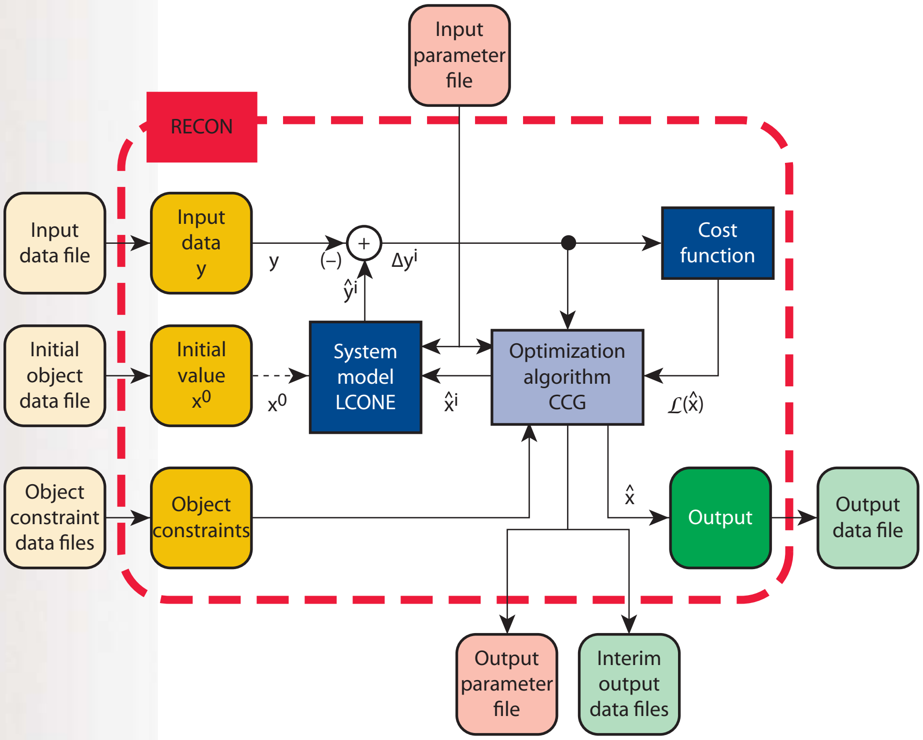

Figure 1. RECON-CCG-LCONE model.

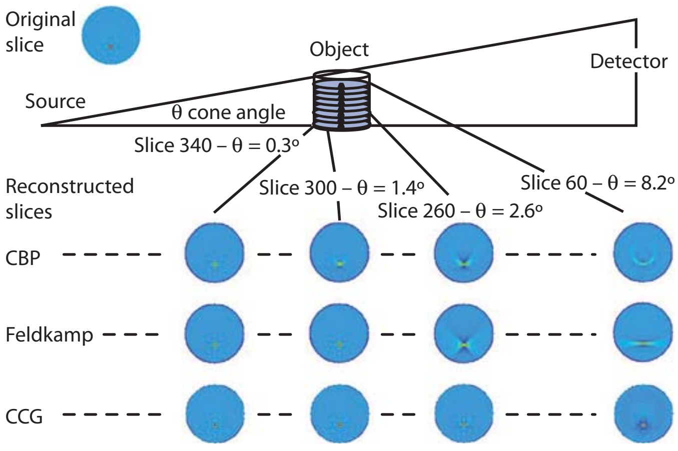

Figure 2. Large cone angle simulated cone-beam reconstruction comparison.

FFTs, and then essentially backprojecting and summing the data. These methods include Filtered Backprojection (FBP), Convoluted Backprojection (CBP), and the Feldkamp Algorithm. FBP and CBP are designed to work on systems with parallel and fan beams, respectively. These beams pass through only one slice of an object. Processing speeds for these methods are generally reasonable even for large detectors. Also the slices can be processed in parallel, further reducing the overall processing time.

Cone-beam systems are more complicated. In a cone-beam system the beam can pass through a number of object slices. FBP and CBP are not designed to work for this case. The Feldkamp algorithm was developed for cone-beam geometries. However, for the sake of speed and memory it makes certain simplifying assumptions, as a result it works reasonably well for small cone angles but it is less effective for larger cone angles.

To provide a method that would produce a more accurate reconstruction for large cone angles an iterative, optimization, cone-beam system was created. The Constrained Conjugate Gradient (CCG) method was selected as the optimization algorithm in combination with a least-squares cost function. A Linear Cone-Beam (LCONE) ray-path system model was created. In fact, a number of different ray-path models have been created in an effort to improve the processing speed. The latest ray-path model based on a polar coordinated system has proved quite effective.

A number of years ago LLNL's NDE staff developed a suite of reconstruction codes called RECON. Included in the system were routines for reading and writing parameter files, known as SCT files, and routines for reading and writing data files in the VIEW file format. CCG-LCONE was created within this system. Figure 1 shows the CCG_LCONE iterative optimization system within RECON.

CCG-LCONE has proved to be effective for cone-beam CT problems. Figure 2 shows a comparison of simulated results for different algorithms. At four different cone angles the reconstruction results are shown for CBP, Feldkamp and CCG-LCONE. CCG-LCONE obviously out performs CBP and Feldkamp.

CCG-LCONE is, however, slow and memory intensive, so it has been generally used only in special cases. One case where it has been effective is in neutron imaging. Neutrons produce noisy data, since they are heavy particles and cause a great deal of scattering. CCG-LCONE has been effective in processing this data, as shown in Fig. 3.

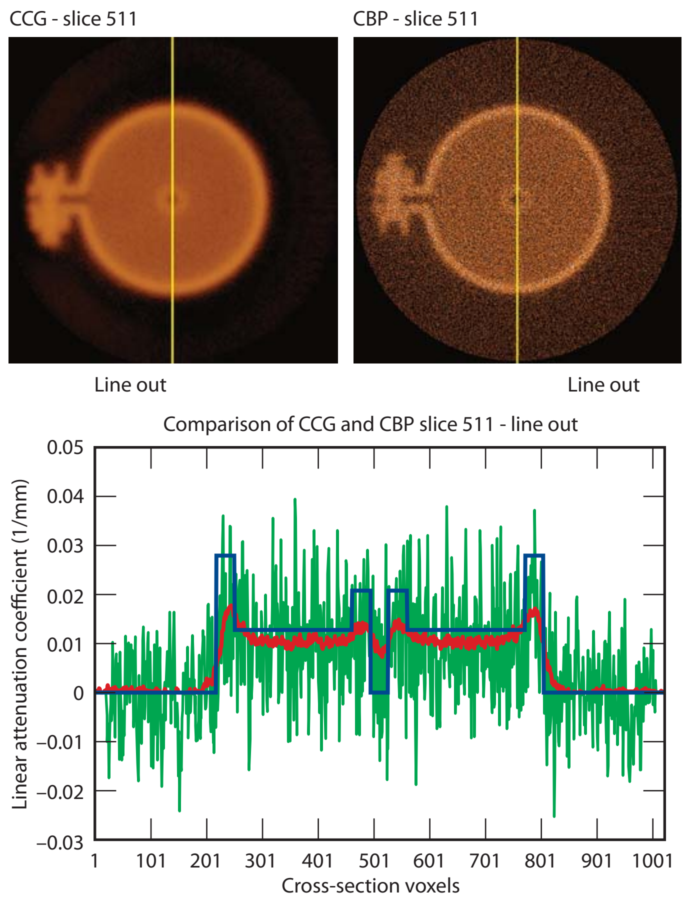

Figure 3. CCG-LCONE (red) and CBP (green) reconstruction comparison for neutron imaging.